Use of Proximal Soil Sensing to Delineate Management Zones in a Commercial Potato Field in Prince Edward Island, Canada

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Abstract. *Management zones (MZs) are delineated areas within an agricultural field with relatively homogenous soil properties. Such MZs can often be used for site-specific management of crop production inputs. The purpose of this study was to determine the efficiency of two proximal soil sensors for delineating MZs in an 8.1-ha commercial potato (Solanum tuberosum L.) field in Prince Edward Island (PEI), Canada. A galvanic contact resistivity sensor (Veris-3100 [Veris]) and electromagnetic induction sensors (DUALEM 21-S [D21S]) were used to measure apparent soil electrical conductivity (EC_a) at different depths according to the specifications of each sensor. The data from the two sensors were used to delineate MZs using an unsupervised fuzzy k-means clustering algorithm. Soil samples (0–15 cm) were collected from 104 georeferenced locations and analyzed to determine the soil physicochemical properties (Mehlich-3 extractable phosphorus [P] and potassium [K], and soil texture). Based on the analysis of the soil EC_a variance, two MZs were found to be optimal. There was a significant difference in soil EC_a between the two MZs (Veris (0-30 cm depth): 4.4 $mS{\cdot}m^{-1}$ vs 6.7 $mS{\cdot}m^{-1}$; and D21S (0-40 cm depth): 3.1 $mS{\cdot}m^{-1}$ vs 4.2 $mS{\cdot}m^{-1}$). The MZs delineated by Veris and D21S were significantly different for P (Veris: 192 $mg{\cdot}kg^{-1}$ vs 212 $mg{\cdot}kg^{-1}$; D21S: 194 $mg{\cdot}kg^{-1}$ vs 215 $mg{\cdot}kg^{-1}$), K (Veris: 92 $mg{\cdot}kg^{-1}$ vs 128 $mg{\cdot}kg^{-1}$; D21S: 97 $mg{\cdot}kg^{-1}$ vs 130 $mg{\cdot}kg^{-1}$), sand (Veris: 690 $g{\cdot}kg^{-1}$ vs 625 $g{\cdot}kg^{-1}$; D21S: 678 $g{\cdot}kg^{-1}$ vs 634 $g{\cdot}kg^{-1}$) and clay (Veris: 78 $g{\cdot}kg^{-1}$ vs 96 $g{\cdot}kg^{-1}$; D21S: 81 $g{\cdot}kg^{-1}$ vs 95 $g{\cdot}kg^{-1}$). The low EC_a zone had lower clay content, and may require site-specific irrigation to make up for the reduced soil water retention capacity. Based on the greater soil test P and K in the high EC_a zone, it may be possible to reduce the P_2O_5 and K_2O application rate in that zone. The Veris and D21S sensors were effective in delimitation of MZs for potential use with site-specific nutrient and irrigation*

management at this site.

Keywords. *Apparent soil electrical conductivity, fuzzy k-means*

Introduction

Conventional farming practices include managing fields uniformly without considering the spatial variation of soil properties and crop yield. This uniform management limits crop productivity, results in inadequate application of inputs, and in detrimental impacts on the environment. Precision agriculture (PA) approach is a way perform agriculture field management by taking the within-field variation into account, and incorporating that variability into management decisions (Haghverdi *et al.*, 2015). One way to apply PA is through the use of management zones (MZs), which are zones within an agricultural field with homogenous soil properties. The MZs allow for site-specific management of agricultural inputs to increase profitability of crop production, improve product quality, and protect the environment (Adamchuk *et al.*, 2004). Proximal soil sensors, which include geophysical instruments to map apparent soil electrical conductivity (EC_a), have been used to characterize the spatial variation of soil properties and to delineate MZs (Adamchuk *et al.*, 2015). The purpose of this study was to compare the efficiency of two proximal soil sensors for delineating MZs in a specific production environment, and to assess the ability of different EC_a maps to subdivide field according to soil texture as well as extractable K and P (as secondary effect of differences in soil texture).

Materials and methods

The study was conducted in a commercial 8.1-ha field under intensive potato (*Solanum tuberosum* L.) production located in Springfield West, PEI, Canada. The two proximal soil sensors used were: 1) Veris (Veris Technologies Inc., model 3100, Salina, KS, USA) and 2) DUALEM (D21S; DUALEM. Inc., model 21-S, Milton, Ontario, Canada). Soil EC_a data were collected on parallel transects spaced approximately 10 m apart at 1 Hz rate, corresponding to a measurement at every 2 to 3 m. Soil EC_a data were taken in 0-30 cm depth for the Veris and in 0-40 cm depth for the D21S. The data from the two sensors were used to subdivide the field into MZs using the unsupervised fuzzy k-means clustering algorithm. This algorithm was carried out using FuzME software (Minasny *et al.*, 2002). Two to five MZs were delineated using the data from the Veris and the D21S individually.

Soil samples (0–0.15 m) were collected from 104 georeferenced sample locations on a triangular grid (30-m x 30-m) and analyzed to determine the soil physicochemical properties (Mehlich-3 extractable phosphorus [P] and potassium [K]), and approximately one sample out of four was analyzed to determine soil particle size (clay, silt and sand content). Pearson correlation analysis was completed to establish the relationship between the proximal soil sensors measurements and the soil physicochemical properties. Within-zone variance reduction was performed to determine the optimal number of MZs. ANOVA was performed using SAS software (SAS Institute, 1985) to determine if the soil physicochemical properties were significantly different between the MZs.

Results and discussion

Significant coefficients of correlation were observed between soil EC_a measured by Veris (0-30 cm depth) and the P (r = 0.22), K (r = 0.34), sand (r = -0.83) and clay (r = 0.84) content. Significant coefficients of correlation were also observed between soil EC_a measured by D21S (0-40 cm depth) and the P (r = 0.20), K (r = 0.33), sand (r = -0.63) and clay (r = 0.74) content. The highest variance reduction within-zone was recorded by delineating the field into two MZs with a total within-zone variance reduction of 65% and 66% for Veris and D21S, respectively. Consequently, two MZs were determined to be optimal for the two proximal soil sensors: a low soil EC_a zone (MZ_1) and a high soil EC_a zone (MZ_2) (Figure 1).

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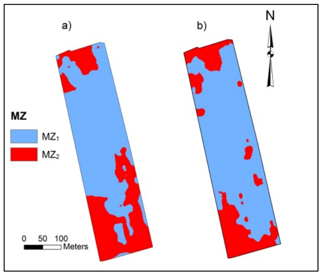

Fig 1. Two management zones (MZs) delineated by a) the Veris and b) the D21S

Significant differences were observed in soil EC_a between the two MZs delineated by the Veris and D21S (Table 1). The MZs delineated by the Veris and D21S sensors showed significant differences for the P, K, sand and clay content with high sand content is presented in MZ_1 and greater values of P, K and clay content are presented in MZ_2 (Table 1). The MZ_1 delineated with the Veris (MZ_1: 65% of the total area) and D21S (MZ_1: 75% of the total area) have similar soil properties (98% similarity). The similarity is of the same order of magnitude for the MZ_2. The MZ_1 has a lower clay content which may result in water deficits and may require site-specific irrigation. Considering the difference in P and K content in each zone, it may be possible to reduce the application rate of P_2O_5 and K_2O in MZ_2, which would save 45 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1}.

Table 1. Comparison of the some soil properties in two management zones (MZs) delineated by the Veris and D21S sensors

MZs	EC_a (mS m^{-1})		Phosphorus (mg P kg^{-1})		Potassium (mg K kg^{-1})		Sand (g kg^{-1})		Clay (g kg^{-1})	
	Veris	D21S	Veris	D21S	Veris	D21S	Veris	D21S	Veris	D21S
MZ_1	4.4 a*	3.1 a	192 a	194 a	92 a	97 a	690 a	678 a	78 a	81 a
MZ_2	6.7 b	4.2 b	212 b	215 b	128 b	130 b	625 b	634 b	96 b	95 b

* Properties with different letters are statistically significant at $p < 0.05$ according to the LSD test.

Conclusion

The delineation of the study field into two MZs reduced a large part of the total variance. The Veris and D21S sensors were effective in delineation of MZs for potential use with site-specific nutrient and irrigation management at this site.

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References

Adamchuk V, Allred B, Doolittle J, Grote k & Viscarra RR (2015) Tools for Proximal Soil Sensing.

Adamchuk VI, Hummel J, Morgan M & Upadhyaya S (2004) On-the-go soil sensors for precision agriculture. *Computers and electronics in agriculture* 44(1):71-91.

Haghverdi A, Leib BG, Washington-Allen RA, Ayers PD & Buschermohle MJ (2015) Perspectives on delineating management zones for variable rate irrigation. *Computers and Electronics in Agriculture* 117:154-167.

Minasny B & McBratney A (2002) FuzME version 3.0. *Australian Centre for Precision Agriculture, The University of Sydney, Australia.*

SAS Institute (1985) SAS user's guide: statistics. *Version 5th Edition. SAS Institute Inc., Cary, NC.*

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